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Electricity in Mining.

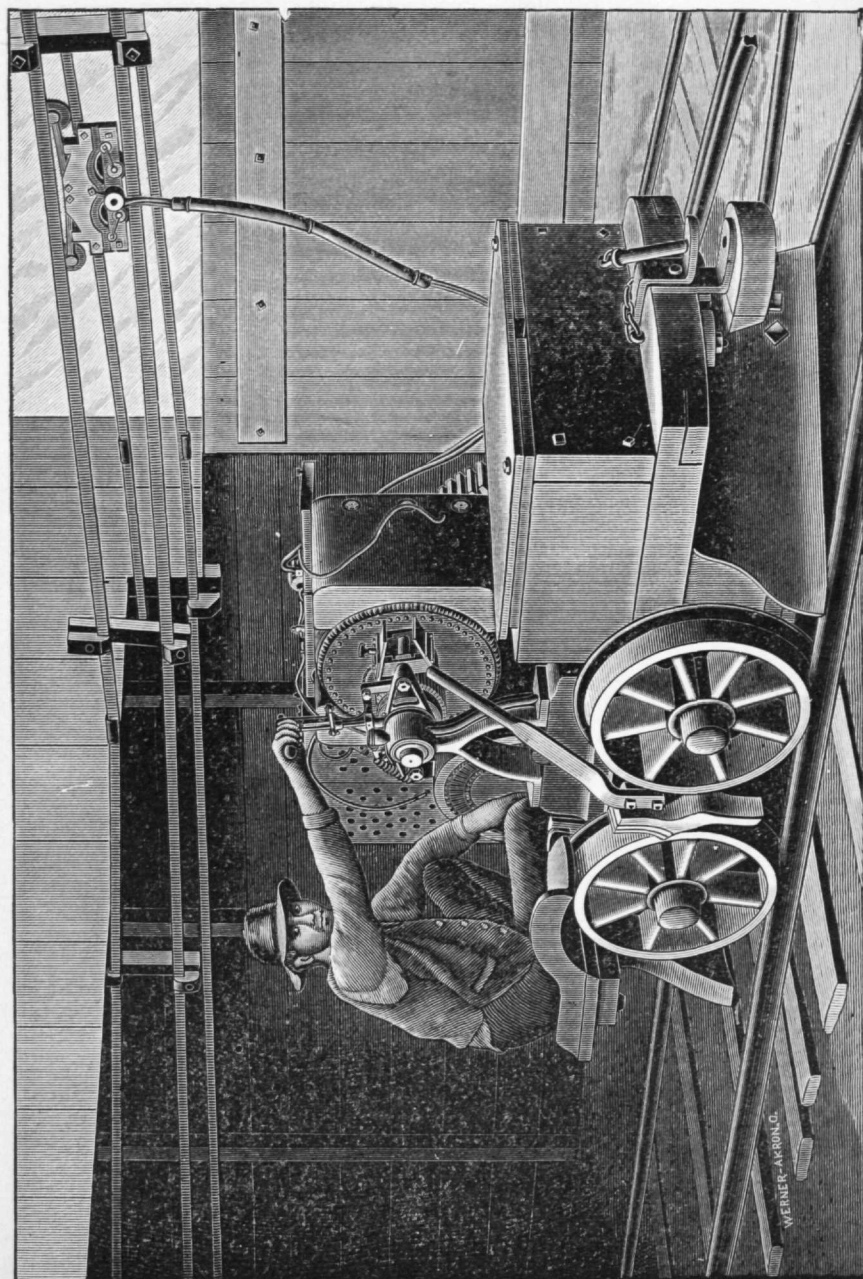
BY R. M. HASELTINE.

The phenomenal feature of advancement in mining in the State during the year just closed has been the introduction of electricity as a motive power in our mines, by the means of which to reclaim our coal. Its adaptability and many commendable features have enlivened a great interest among those who are engaged in the industry. The Department has been in receipt of many inquiries, as to the progress that has been made, from operators in our own as well of those of our sister states. It is not the province of the Department to criticise any feature of the different systems in use or any particular electrical plant that has been erected in the State, neither is it the desire to enlarge upon those which, it can be truthfully said, are doing economical work at the close of the year. That its application has been as successful in each instance to the degree that its advocates desired can hardly be claimed; the failure of a single branch when tested at one mine has been successfully applied in another, and this fact may account for many conflicting reports in mining circles as to the degree of proficiency to which it had arrived in the endeavor to apply this new power to man's use in this great branch of the industry in the State. While the practical application of electricity as yet attained is far short of the claims which are made for it by those interested in the manufacture of the various machines so essential in the mining industry, sufficient proof has already been furnished to demonstrate to any practical person who has given the matter any at-

tention, that the economical production of coal by the use of electricity in many portions of the State is only a matter of a very short time. As the subject is a new one to many of those who are interested in mining in the State, it may not be out of place to describe as briefly as possible the progress made by those who have been foremost in the introduction of it in our mines.

The first installation of electric mining machinery in the State was undertaken by the Shawnee & Ironpoint Coal & Iron Co. at their Whip-poor-will mine at Shawnee in Perry Co. under Mr. Eli Hull, the General Manager. The contract for the steam plant was given to the Taylor Manufacturing Co. of Chambersburg, Pa., and the contract for the electrical machinery, consisting of a forty horse-power dynamo, an eight horse-power excitor and a fifteen horse power-motor, also the line conductors, etc., with the exception of the car frame, the gearing and regulation, was given to Messrs. Bidwell & Kimball, of Chicago, on Aug. 5th, 1888. The erection of the line conductors and the work of fitting the motor to the car was at first under the supervision of Mr. Bidwell.

During that time the plan adopted was to carry the electric current by means of two channel iron conductors each of which were placed just inside of the rails on three by five stringers to which they were securely fastened, the stringers were bolted to the ties; this left the conductors about four inches above the surface of the ground. The reason, says one of the contractors, for placing the conductors in this unusual position was in the first place, to put them where the miners would be least likely to come in contact with them and in the second place to make the system conform as nearly as seemed practicable to the so-called Bidwell conduit system for street railways. The fact that no similar electric conduit even when installed with the greatest care and expense in the paved streets of the cities, had been more than partially successful did not deter them from the very crudest repetition of the same experiment at a coal mine. The motor car was purchased at Barnesville and was entirely of wood except the wheels and axles and was little better adapted for the work than an ordinary bank car; with this car, weighing less than three thousand pounds, the plan proposed was to draw a train of ten empty bank cars up an incline plane of eight hundred feet in length having a uniform grade of eight feet per hundred. The machinery and conductors having been put in place at a great expense, the contractors directed the first trial of the motor car on Dec. 23d, 1888, when it was found to not have sufficient traction to even move its own weight on the incline. New and unforeseen difficulties presented themselves



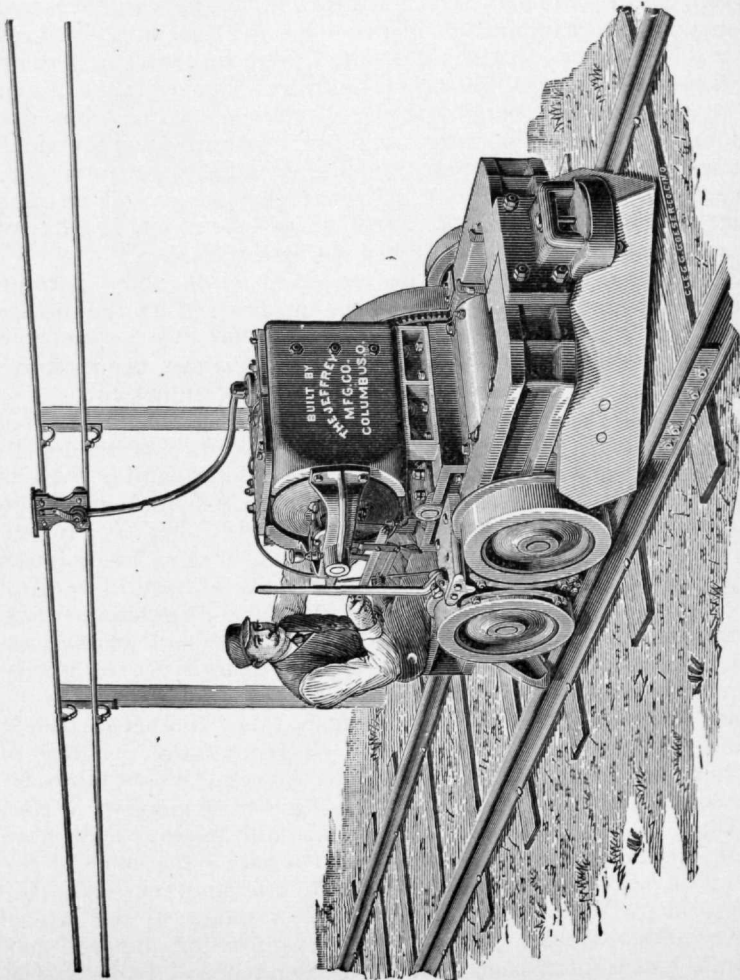
CUT OF THE MOTOR BUILT AT THE NEWARK MACHINE SHOP, WHICH WAS THE SECOND MOTOR OPERATED IN OHIO.

owing to the position of the channel iron conductors, involving mechanical difficulties in switches and trollies that seemed insurmountable; and the plan proposed to haul by means of the motor on the plane was abandoned. About this time Mr. Bidwell severed his connection with the plant and Mr. Kimball assumed the responsibility of entirely changing the plan to that of an overhead system, which, with the assistance of Mr. D. M. Osyerof, of Newark, was successfully accomplished. In this the same channel irons were utilized. This change was completed January 20th, 1889, involving a delay of about three weeks but when completed by the aid of a new trolley having a flexible connection between it and the car, the motor would haul six loaded cars in any portion of the mine except at one point where the grade was from five to six per cent. against the load.

After six weeks use it was found that the chain gearing in use on the motor car was not suitable for the work and that the car was too weak as well as too light, and the trolley at first devised was found in actual use to be also too weak. A new car designed to overcome these difficulties was built at the Newark Machine Shop and was a great improvement over the former, but the designers had not fully appreciated the severity of the work that it must stand, the frame being of wood only lasted about six months. About the first of September a new motor car of similar design but of much greater strength and power was built by the Jeffrey Manufacturing Co. of Columbus. This motor car weighing five tons has been continuously hauling from the gathering partings in the mine to the head of the incline, since it was installed. Its maximum load is thirty tons encountering grades of four per cent. against the load making the round trip in seven minutes, the distance being twenty-four hundred feet. A new trolley with four grooved wheels so arranged as to run between the bars of channel iron, which are placed about eight or ten inches apart, was also designed and the current is taken from the trolley to the motor car by separate wires which are perfectly insulated and encased in a small cable. A still newer trolley-line has been designed by the Jeffrey Mfg. Co., consisting of two lines of gas pipe one inch in diameter, encasing a copper wire; these are placed one above the other about one foot apart and the trolley is constructed with two grooved wheels so arranged as to run on top of the gas pipe. It is said to be much cheaper to construct and at the same time forms a more perfect circuit than any line yet in use.

At the power house a sixty-seven horse-power engine running at three hundred revolutions per minute maintains a pressure of two hundred and fifty volts, the motor uses sixty amperes while drawing the train on the level and ninety amperes while on

the grade, being sixteen and one-third, and thirty horse-power respectively. The mining machine was built by the Jeffrey Mfg. Co., and was delivered during the month of April. As the power plant had been completed and the conductors placed in the mine during the establishment of the haulage plant no delay was occasioned in setting it at work on its arrival. With the exception of changing one gear wheel to lower its speed it has run continuously ever since. This is said and it is truthfully believed to have been the first economical electric mining machine installed in the United States.

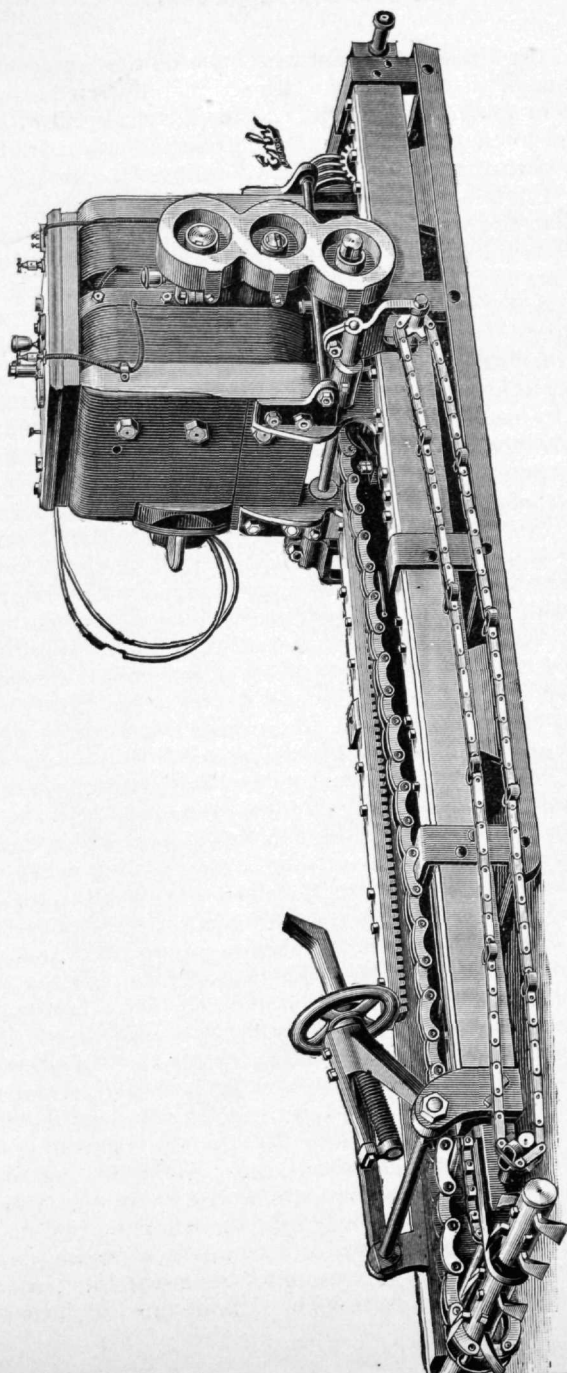


THE JEFFREY MOTOR CAR.

The writer witnessed the machine at work during the month of October.

The bearing in here is made in the fire clay which forms the coal floor of this region, and the average time consumed in making the cut was five and one-half minutes, the bar being three and one-fourth feet in length, and the depth of under-cut was six feet. Owing to the lack of experience of one of the men in handling the cutting machines and the softness of the coal floor, nine minutes was consumed in resetting the machine between cuts and at this rate, the time necessary to make the under cut in a room twenty-seven feet in width would be two hours and eight minutes. The coal vein at this point is three feet seven inches in thickness, and it will be seen that a room will produce twenty-one and one-half tons of coal (run of mine). The time required in moving the cutting machine from one room to another was thirty minutes; this was equally divided between the loading, moving and unloading preparatory to starting on the next room. From the above it will be seen that two men will make the under-cut of four rooms in a day of ten hours which will yield eighty-six tons of coal.

This can undoubtedly be increased as the men become more experienced in handling the machine. At the power plant was maintained a pressure of 250 volts, and the machine was consuming about sixty amperes equaling twenty-horse power; the main conductor is of No. 4 wrought wire. The inside conductors are No. 3 and No. 4 wire woven into a cable composed of four wires, the system being known as the double conductor circuit. A volt is a gauge of pressure and derives its name from Volta, the name of a celebrated Italian scientist who gave us the first electric battery so called Voltapile. In hydraulics it is the equivalent of waterhead, or in steam it equals the pounds of pressure per square inch. An ampere is a unit of quantity and derives its name from Ampere, a French scientist, who gave us some of the fundamental theorems of magnetism. In mechanics it represents the unit of quantity of electricity flowing through the conductor in one second. It really is the unit of velocity, and as a further illustration: If a person should hold a vessel under a spout for one second the quantity of water that would pass through it into the vessel would represent in hydraulics the equivalent of the number of amperes in electricity. Seven hundred and forty-six volt amperes is equal to one mechanical horse power. A coulomb is the name of the total quantity passing through a conductor and represents the sum total of amperes per second. For instance, at the rate of sixty amperes at the end of a minute thirty-six hundred coulombs will have passed through the conductor. It derives its



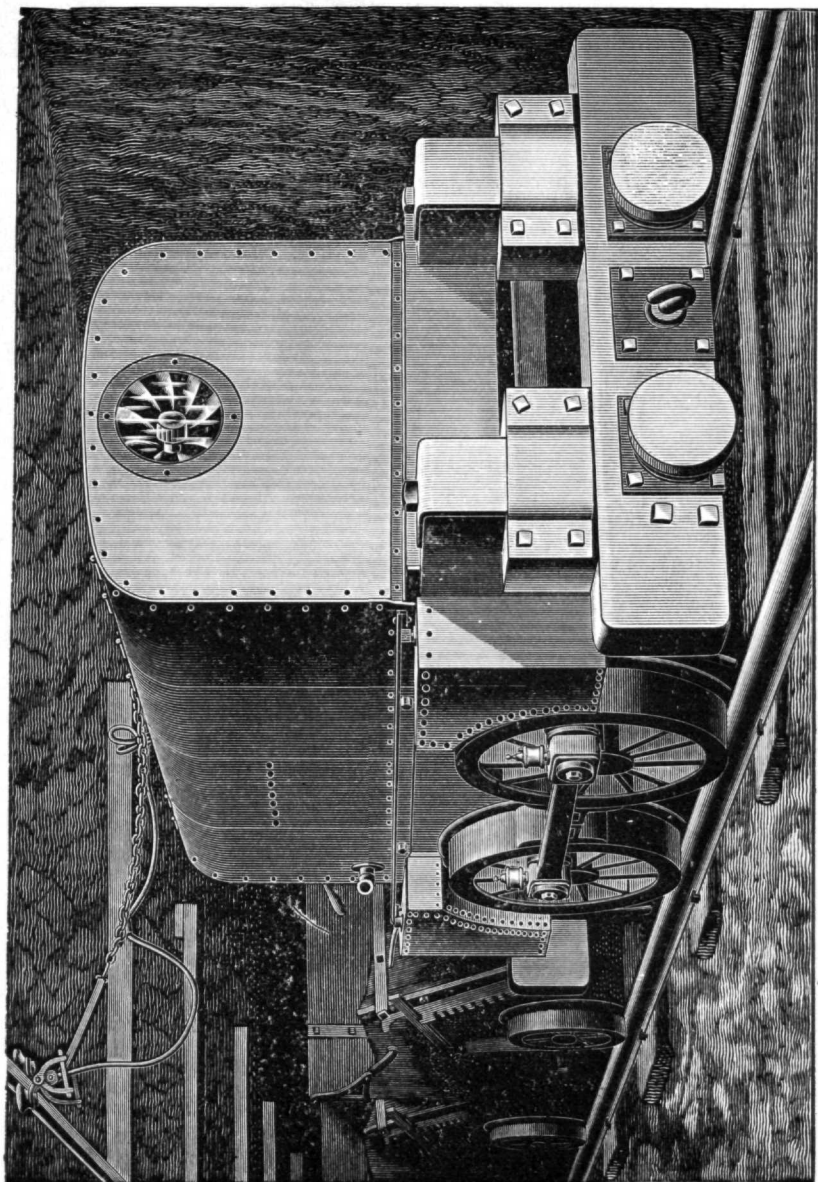
THE JEFFREY ELECTRIC MINING MACHINE.

name from the French scientist who gave us the laws governing the influence of distance or the attraction between two electrified bodies or magnets. A watt is the electrical unit of power, and is equal to one volt ampere or the one seven-hundredth and forty-sixth part of a horse power, and derives its name from the celebrated English engineer Watt. In the computation it will be seen that the machine when using sixty amperes under a pressure of two hundred and fifty volts consumes twenty-horse power, as seven hundred and forty-six divided by two hundred and fifty equals 2.98 amperes, then under this pressure we find that it requires two and ninety-eight one hundredths amperes to yield one mechanical horse power. Sixty amperes divided by 2.98 equal twenty-horse power or two hundred and forty volts multiplied by sixty (the amperes) and divided by 146 will equal twenty-horse power which is required to drive the machine and undermine the coal in the time mentioned.

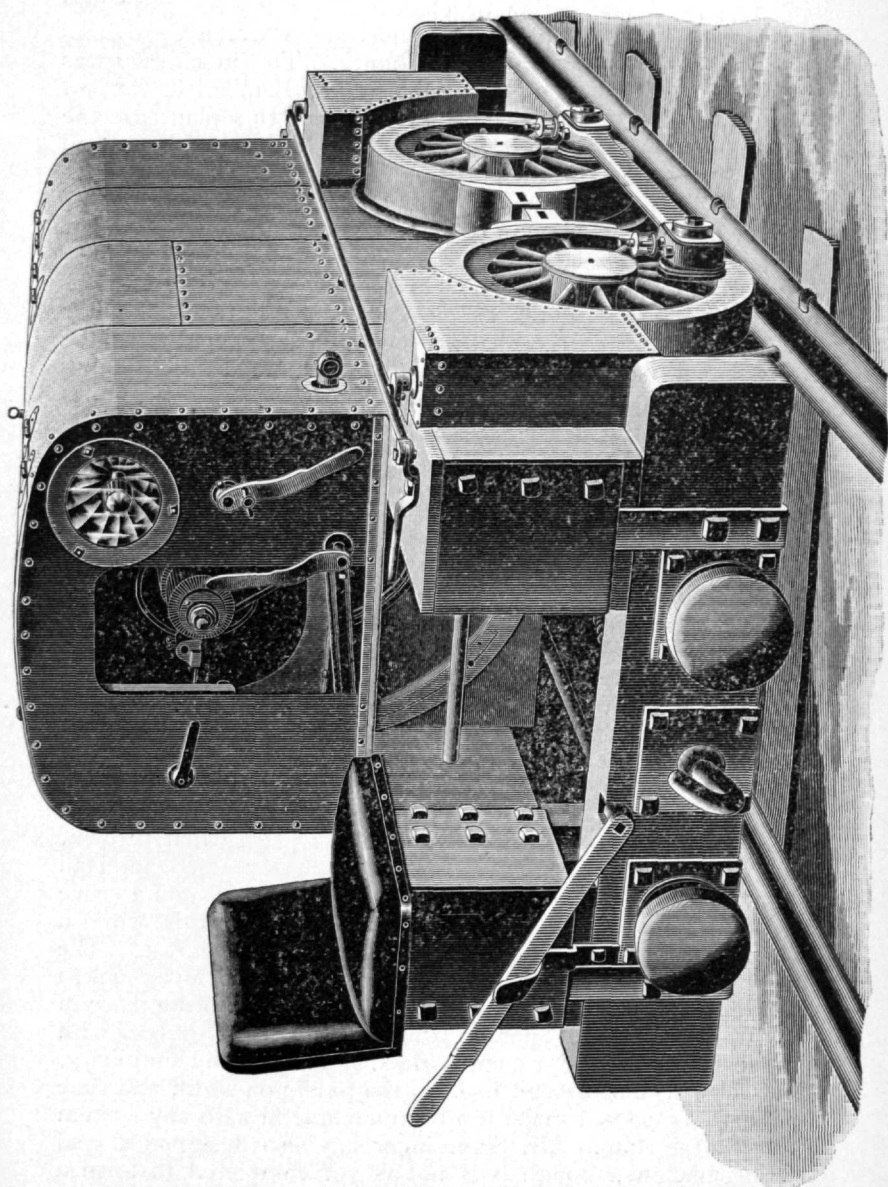
The second contract made in the state was entered into Dec. 17th, 1888, between the Sprague Electric Rail Road and Motor Company, of New York, and Mr. Wm. Job, for Ellsworth, Morris & Co. This contract provides for the erection of one 150-horse power steam engine and two 75-horse power dynamos and the equipment of their Brush Fork Mine, No. 2, in Hocking County, with one 15-horse power motor car, six 15-horse power mining machines and three single horse power motor drills, all by April 15th, 1889. The first application of electricity was made on the motor car some time in June, and at this trial it was found able to draw but three loaded mine cars weighing two and one-half tons each up a two per cent. grade. It is said that to accomplish this it required a quantity of electrical power equal to 15 mechanical horse power. This result was not as satisfactory as had been expected as the common working load for a horse over this road in the past has been five loaded cars. During September, a second trial was made under the direction of another electrician who used a much larger conductor. This trial resulted in the same motor drawing with ease ten loaded cars equaling twenty-five tons, over the same road, using the same electrical power to perform the work. The marked improvement in this over the former trial, demonstrated that when properly applied, it would prove a success in economically handling the coal in our mines. Mr. Job was so favorably impressed with the experiment that shortly thereafter he began equipping their No. 3 mine, which is located on the opposite side of the ravine from the one just described, with a view of hauling coal from the extreme portions of the mine to the end of the present tail-rope system. In equipping this mine, No. 0 wire, which is about three-eighths of an

inch in diameter, was used for the main conductor to which the trolley line composed of two No. 3 wires is connected. The double line system being the one in use here, the trolley is constructed to run on top of these conductors. It was near the close of the year before all was completed and working successfully. The motor car used in the first trials weighs about three tons here and pushes ten loaded mine cars which weigh in the aggregate twenty-five tons, on an entry 1,600 feet in length, encountering grades against the load as great as three per cent. The time usually required in making the round trip is eight minutes. To accomplish this, a pressure of 230 volts was maintained at the power-house, the motor using 60 amperes. It will be seen that to perform this work requires 230 volts multiplied by 60 amperes, divided by 746, equals eighteen and one-half horse power, which is required to move the motor and the load of twenty-five tons along this entry at the speed before described.

During the month of September, Mr. Job placed in the mine an electric mining machine made in Columbus by the Jeffrey Manufacturing Company, which differs from the compressed air machines made by them in substituting the electric motor for the engines designed for the use of compressed air. Some difficulty was at first experienced in adjusting the brushes on the commutator for want of experience in hauling this new power; this was soon overcome, however, and the machine has run continuously to the close of the year. To operate the machine, a pressure of 230 volts was maintained at the power-house, and a consumption of 50 amperes was required equaling 15.4-10 mechanical horse power. The writer witnessed this machine at work on different occasions. The bearing in being in the coal, the average time in making a cut six feet under with a cutting bar three and one-fourth feet in length, was six minutes and fifty seconds; the time consumed running back, twenty-seconds; and run back and set, one minute and seven seconds, though one set was made in fifty-three seconds. The rooms are driven twenty-six feet in width, so that eight cuts and seven sets will finish a room requiring one hour, two and one-half minutes to perform the work. To move this machine, which weighs about 2,400 pounds, from one room to another, required twenty minutes, and at this rate two men in this vein, which is seven feet in thickness, would undercut 177 tons of lump coal in nine hours. It will, however, be just to say that this exhibition was made by Clarey Well and John Baws, two experienced men, as was shown by their being able to make a run back and set in the extraordinary short time of fifty-three seconds.



FRONT VIEW OF THE SCHLESINGER MOTOR AT WORK IN MINE NO. 19 OF SUNDAY CREEK COAL COMPANY.



REAR VIEW OF THE SCHLESINGER MOTOR, SHOWING THE LEVERS FOR ITS OPERATION.

The third installation of electricity during the year was made at mine No. 19, owned by the Sunday Creek Coal Company, at Buckingham, in Perry County. The machinery was built and erected by Messrs. Schlesinger, Kimball & Co., of Columbus. The designs and application of this plant are the inventions of Mr. W. M. Schlesinger, a German engineer and inventor of what is known as the Schlesinger system of electricity. The power plant consists of a 110-horse power engine which runs at a speed of 170 revolutions per minute. The electrical power derived from a 100-horse power dynamo running 500 revolutions per minute. This is conveyed through a drill-hole in the floor of the power-house to a point in the main entry near the bottom of the shaft, where it is connected with the trolley line, which consists of a line of 14 pound T rail running along the entry at such a height as to allow persons and mules to pass under it in safety. On this rail the trolley runs, which is so constructed that by means of a spring, the wheels (four in number) clamp the head of the rail in such manner as to run on the web of the rail. From the trolley to the motor car the current is carried by means of a series of wires encased in a cover, securely insulating it from danger of contact with those who operate the motor car, which is also the design of Mr. Schlesinger. It weighs three and one-half tons, and is intended to exert 35-horse power. While it has been in operation but a few weeks it is doing good work. The line of entry over which it runs, is 1,250 feet in length, drawing a train consisting of 18 or 23 cars, making an aggregate load of about 60 tons. These it gathers from a half dozen partings in the mine. To run from one entry to another, Mr. Schlesinger has devised a very simple but ingenious switch in the conductor rail, which is readily moved and remains perfectly rigid in its place when thrown. At one of the gathering partings, the motor starts its load against the grade of four and one-half per cent.; also on a curve having a radius of twelve feet. In performing this work a pressure of 440 volts is maintained at the power-house. The motor at its general work, uses 50 amperes, which is equal to 29½-horse power. It has supplanted in this mine the place of ten mules. To the operator this haulage plant glitters with practical features. For compactness, symmetry and simplicity, the motor will commend itself to the public on sight, and time and experience will make it a formidable rival with any system in use in the state. Mr. Schlesinger has also designed a coal cutting machine, though it is not as yet completed to form a feature in this article, beyond a brief description. It is composed of eleven drills two inches in diameter running horizontally, and so set that the perimeter of one cuts the perimeter of



CUT OF THE SCHLESINGER TROLLEY LINE AND SWITCH IN PLACE IN THE MINE.

the other. They are designed to make an under-cut three feet in width and four to six feet in depth. Its weight when complete is 1,300 pounds, and it is said to resemble in principle a machine using compressed air that has given general satisfaction. When perfected, owing to its weight and form, it will be especially adapted to working the thin seams of coal in the State. Much has been written and great alarm has been manifested as to the danger arising from coming in contact with the conductors, but the experience at the mines where electricity has been installed is that a 500 volt current is harmless to persons simply coming in contact with the conductors. The writer has repeatedly witnessed persons holding both wires of a double circuit for several minutes that were under a pressure of 250 volts. A pressure of 1,000 volts is supposed to be the danger limit of instantaneous touch, though it has been proven not to be always fatal, which is perhaps due to the condition of the human system at the time of contact, or rather the circumstances surrounding the person at the time of contact. Some persons are less susceptible to its influences than others. The danger of injury from coming in contact with the conductors depends on the pressure or voltage and the length of time the person is subject to that pressure. The length of time necessary for it to become fatal rapidly decreases with the increase of pressure, so that at some pressure above 1,000 volts, touch becomes instantaneously fatal.

Much has been written, and many extravagant claims have been made, by persons engaged in the manufacture and installation of electric motor cars, as to their increased efficiency over like locomotives that are propelled by steam. This, it is claimed, is superinduced by passing an electrical current through the driving wheels into the rails, thereby greatly increasing the co-efficient of adhesion of the wheels on the rails. An instance is frequently given where an experiment was made by an experienced engineer of the Philadelphia & Reading R. R., who placed a dynamo on his locomotive, and by passing a strong electrical current through the driving wheels into the rails, he was able to increase the efficiency of his engine 40 per cent. The writer is not aware of there ever having been an official report made of this experiment which is so often alluded to by electricians.

With a view of determining the truth or fallacy of the claims made by electricians on this subject, I have made calculations as to what a steam locomotive of equal weight would draw on the entries in the three mines of the State that are now hauling coal by electric motors. In doing this, it is unfortunate that no reliable experiments are made public as having been made

on mine cars to determine the resistance that has to be overcome due to axle bearings, grades and curves that are encountered in our mines of the State. We are also in the dark as to the co-efficient of adhesion that would be applicable to the rails in the mines. Authorities differ widely on this question in railroad practice, they varying from 1-20 to 1-3. They all agree that the adhesion of a locomotive is much greater when running at a low rate of speed than at a high one. Edwards on Locomotive Engines, places the adhesion on dry rails when sanded, at $\frac{1}{3}$ of the weight on the drivers. Capt. Galton, in a paper read before the Institute of Mechanical Engineers, places the efficiency when sand is applied at the moment of starting, or when it is not blown away by the wind produced by the rapid revolution of the wheels, at from 35 to 40 per cent. of the weight upon the driving wheels. An author in writing of this subject, says that most of the early experiments made to determine the adhesion of the driving wheels on the rails have given dynamic friction, which is the sliding friction of the wheels, and not the static friction, which is when the wheels roll and do not slip. The fact that until recently the distinction was not recognized, he attributes as the reason for the great discrepancies in the data given on the subject.

In consideration of the fact that all the tracks in the mines herein considered have been drained, are as dry as the atmosphere of the mine will permit and the additional fact that sand is liberally applied at all times and the low speed attained by the train the writer determined to use the co-efficient of adhesion 1-3 or .33 equal to 667 pounds per ton of the weight on the drivers. The dust which arises in the mine when it is composed of finely pulverized coal, instead of acting as an element to increase adhesion will on the contrary become a lubricant and to what extent it will decrease the absolute co-efficient of adhesion has never been determined. It is assumed however, to not be of sufficient importance to reduce the adhesion below that given above.

It will be remembered that the claims of increased adhesion are only made on motor cars in use where the return current is conducted by means of the rails, the current passing from the conductor to the motor, thence through the wheels to the rails. In the first two comparisons made, this is not the case, as the system there in use is known as the double conductor, or double wire system, and no claims of increased adhesion is made in these instances. They are used in this computation for the double purpose of determining the applicability of the formulae used for determining the resistance due to railroad trains when applied to ascertain the resistance necessary to be overcome in

trains composed of mine cars, and second to furnish a means of comparison between the efficiency of the two electric systems when applied under similar circumstances.

By the aid of formulae used in railroad work as given by Edwards on Locomotive Engines, Haswell and others, the following comparative results are obtained: In the Sprague motor in use at the Ellsworth & Morris mine in Hocking county, the proposition there presented is, what will a locomotive weighing three tons draw on a straight road, on a grade of three per cent. against the load, at a speed of four miles per hour.

We have resistance due to train on straight line.....	6 lbs.
“ “ “ speed $\sqrt{2}$09 lbs.

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“ “ “ grade $158.4 \times .3815$	60.4 lbs.
Total resistance due to each ton of the train.....	66.49 lbs.

Weight of locomotive 6000 lbs. $\times .33$ = 1980 lbs., which is the total adhesion due to the locomotive.

On each ton of the train it has been found there is a resistance of 66.49 lbs. then 1980 divided by 66.49 equals 29.6 tons, the maximum load a locomotive will draw under above conditions. From this deduct three tons, the weight of the locomotive, the result 26.6 tons, represents the weight of the train drawn. As the motor is regularly drawing a load of twenty-five tons, this shows a loss of 1.6 tons, against the motor car or a loss of 9.4 per cent.

At the mine of the Shawnee & Ironpoint Coal Co., in Perry Co., where the Jeffrey motor is working, this proposition is presented:

What weight of train will a motor weighing five tons, draw up a grade of 211 feet per mile, at the rate of 3.5 miles per hour.

For each ton train, resistance on level track.....	6 lbs.
For resistance due to speed.....	.07 lbs.
“ “ “ grade.....	80.5 lbs.
Total train resistance per ton of train	86.57 lbs.

Weight of locomotive 10000 lbs. multiplied by .33 equals 3300 lbs., adhesive power due to locomotive, 3300 lbs. divided by 86.57 lbs. equals 38.1 tons, the entire effective power of the locomotive. From this deduct five tons for the weight of the locomotive. The result 33.1 tons equals the weight of train it is capable of moving. The motor hauls regularly 30 tons; this is a loss of 1.3 tons, or 4 per cent. against the motor car, which is the same as in the first instance.

At mine No. 19, owned by the Sunday Creek Coal Co., at Buckingham, in Perry Co., the Schlesinger motor and system

there at work, presents this proposition: What will a locomotive weighing four tons draw on a four and a half per cent. grade, around a curve of eleven feet radius (the grade on curve beginning with a four and a half per cent. and ending with a grade of one per cent.) at a speed of four miles per hour?

The length of the motor car being 9 feet. Length of mine car 8 feet. Weight of mine car when loaded, 5000 lbs. Here a new element, that of guage and curve enter the computation.

Before entering into this computation it will be observed that this is the only mine in the State where the current is returned through the rails, consequently, the only opportunity that is presented under the writer's observation of drawing a comparison between the two systems with a view of determining the foundation for the claim of increased adhesion produced by passing the electrical current through the driving wheels into the rails.

The train resistance remaining the same 6 lbs.

The formula $\frac{1}{\sqrt{2}}$ equals 16 divided by 171 equals,

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Resistance due to speed093 lbs.

“ “ grade 2000×4.5 90 lbs.

100

Total train resistance per ton of train due to grade, speed and train resistance of that portion of the grade on which the track is straight..... 96.093 lbs.

On the curve the train resistance remains constant at 6 lbs.

The resistance due to speed remains the same..... .09 lbs.

The grade (receding from 4.5 per cent. to 1 per cent., average grade $2.75 \times .3815$)..... 55.3 lbs.

Curve resistance (.125 for each foot in width of guage equals $3 \times .375 \times 528$ D. C.)..... 198 lbs.

Train resistance due to each ton on the curve..... 259.39 lbs.

Degree of curve, 528. Length of curve, 17 feet.

It will be seen that two cars are on the curve and five tons on the curve will have a resistance of 5 multiplied by 259.39-1296.95. One ton of the locomotive has an adhesion of 2000 lbs. multiplied by .33 equals 667 lbs. Then will 1296.95 lbs., the resistance offered by five tons on the curve, divided by 667 lbs., the adhesion of each ton of the locomotive, give 1.94 tons of the power of the locomotive that is required to draw that portion of the train that is on the curve.

The locomotive weighs four tons ; we then have four tons less 1.94 tons which equals 2.06 tons remaining to draw that portion of the train remaining on the grade.

$2.06 \times 2000 \times .33$ equals 1359.6 lbs., the adhesive weight of the locomotive remaining to overcome the train on the grade.

Total resistance of ton on the grade equals 96.093 lbs.

The unexpended power of the locomotive is 1359.6 lbs., which divided by 96.093 lbs., the resistance due to each ton upon the grade, will equal 14.05 tons. The total load that a locomotive weighing four tons can draw on this grade and around the curve will be 14.1 tons plus 5 tons equals 19.1 tons, less the weight of the locomotive, which is 4 tons, equals 15.1 tons, the load drawn by an ordinary steam locomotive.

The weight drawn by the electric locomotive over the same road, is 22.5 tons, which shows an increase in efficiency of 7.4 tons ; this equals a gain of 49.1 per cent. in favor of the motor car. The percentage of gain in the above instance being so marked in order to furnish (if possible) further illustration, I submit the *reported* work that is being performed at Lykens, Pa., where a Schlesinger motor weighing five and one-half tons is drawing a train weighing 165 tons on a level road passing over two curves having a radius of twenty-two and thirty feet respectively. The tangent between them being 180 feet. The average speed of the train is three miles per hour.

Length of motor, 12 feet. Length of car, 11 feet. Length of train, 380 feet. Weight of car when loaded, 5 tons.

Due to train resistance.....	6	lbs.
Resistance due to speed, 9 divided by 172.....	.05	lbs.
Resistance due to the first curve (length 34.5 feet		
D. of C. 260, equals $.125 \times 3 \times 260$	97.5	lbs.
Total resistance due to each ton on the first		
curve	103.55	lbs.

There being three cars on the curve weighing five tons each, there is 15×103.55 equals 1553.25 lbs. The resistance due to that portion of the train on the first curve. This divided by 667, the adhesion due each ton of the locomotive, it will be seen that 2.33 tons of the motor have been absorbed.

On the second curve the length is 47.1 feet, and the degree of curve is 190.

Due to train resistance.....	6	lbs.
" speed05	lbs.
" curve, $.125 \times 3 \times 190$ equals.....	71.25	lbs.
Resistance due to each ton on the second curve is....	77.31	lbs.
There being four cars equalling twenty tons on the		
curve which multiplied by 77.3, equals.....	1546	lbs.
the resistance due to that portion of the train on the curve.		

The 1546 divided by 667 will equal 2.31 tons of the engine's power that is absorbed on the second curve. There has now been 2.33 tons plus 2.31 which equals 4.64 tons of the engine's power consumed on the curves and .86 of a ton remains to be applied to the remainder of the train which is able to haul $.86 \times 2000$ equals 1720 lbs. $\times .33$ equals 572.7 lbs. which, divided by 6 (the train resistance) equals 95.5 tons that can be drawn in addition to the thirty-five tons on the curves; this equals 130.5 tons, the total power of the locomotive from which is to be deducted 5.5 tons, which is the weight of the engine, leaving 125 tons for the weight of train drawn. As the electric motor is reported as regularly drawing 165 tons the above result shows an increased efficiency of thirty-two per cent. over a steam locomotive of equal weight.

The data for these calculations was gathered by the best means at hand as no scientific tests have been made, and until experiments have been made to accurately determine the exact co-efficient of train resistance, also the resistance due to the irregularly laid curves in the mines, the adhesion on mine rails, and to what extent coal dust enters into its reduction, also to determine the accurate rate at which the train enters the curve and the speed at which it leaves it, so that the law of live force (which has of necessity been omitted in these cases) can be applied, it is doubtful if any more reliable results than that by comparison as above shown, can be obtained.

January 1st, 1890.

There being no discussion on Mr. Haseltine's paper, Capt. Morris moved a vote of thanks be tendered the writer for his scientific paper, which was carried.

A very able paper by Mr. T. F. Smith, of Mineral Point, advocating that large shafts are not necessary to insure good ventilation in mines, was next read by the author. It was discussed with considerable interest by Mr. Bell, Mr. John C. Allen and Mr. T. L. Watkins, Capt. Morris, Mr. Collier and others. Mr. Smith defending his position by referring to different authors on the subject with commendable ability. During the discussion, Senator Zimmerman favored the Institute with a visit and was invited to a seat on the stage with the President and Secretary.